

APPENDIX VI: PROTOCOL DEVELOPMENT SUMMARIES

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PROTOCOL DEVELOPMENT SUMMARY

Protocol: Amphibians

Parks Where Protocol will be Implemented: YELL, GRTE, BICA

Justification/Issues being addressed: Declines in the abundance and distribution of amphibians have been widely recognized as an emerging issue (Stuart et al. 2004). Concerns regarding such declines resulted in the funding of the Amphibian Research and Monitoring Initiative (ARMI) in 2000. ARMI is a national program coordinated by the U.S. Geological Survey (USGS), with the goal of better understanding the dynamics of amphibian population trends and providing the information necessary to guide management decisions to manage and conserve amphibian populations.

Our specific monitoring objectives are intended to answer the following question(s): Is the occurrence of amphibians decreasing within the Greater Yellowstone Network of parks (GRYN) and is there any evidence regarding likely underlying causes of any observed declines that might warrant further directed research or management actions consistent with National Park Service policies? Although our specific monitoring objectives are targeted for inferences to the GRYN, they are also intended to complement broader objectives of ARMI that would seek to answer similar questions at more regional and/or national scales.

Monitoring Questions Addressed by the Protocol:

Some of the specific monitoring questions that will be addressed by this protocol include:

- What is the proportion of breeding sites (wetlands) within the GRYN occupied by each species of amphibian?
- What are the extinction and colonization rates of breeding sites within the GRYN, and are these rates associated primarily with whether or not sites are inundated within a given year?

Specific Monitoring Objectives:

Objective 1. To estimate the proportion of catchments (approximately 8th order) within YELL and GRTE used for breeding by each of each species of amphibian and to estimate the rate at which use of these sites for breeding is changing over time (except boreal toads, see Objective # 2).

Justification/Rationale for this objective.-- Actual population estimates for most amphibians are not logistically feasible due to substantial variability in detection of adults and in highly variable populations both within and among years (Corn et al. 2004). The use of sites for breeding should provide a more consistent measure of the occupancy of sites, at least for this life stage.

Objective 2. To estimate the proportion of catchments (approximately 8th order) and targeted

breeding sites within YELL and GRTE used for breeding by boreal toads (*Bufo boreas*) and to estimate changes in occupancy of targeted breeding sites over time.

Justification/Rationale for this objective.-- Boreal toads present a special case in that they are sufficiently rare so as to make estimation of rates of change difficult from a sampling scheme with a targeted scope of inference to the entire parks. Preliminary sampling indicates that the proportion of sites occupied by boreal toads is too low to enable reliable estimation of rates of change. Thus, the major distinction between this objective for boreal toads and that of the other species is that our sampling frame for change over time would be restricted to a targeted set of known potential breeding locations. This will limit our inference to change over time for these specific sites, but these probably represent the primary breeding sites for this species.

Objective 3. To estimate the proportion of potential breeding sites (i.e. wetlands) that are minimally suitable for breeding (i.e., have standing water) in any given year.

Justification/Rationale for this objective.-- For reliable comparisons of change in occupancy over time, the sampling frame must be the same from year to year. The occupancy estimator carries the assumption that sites have a non-zero probability of being occupied at the time that estimates are made. However, during some years, some wetlands have a probability of zero that amphibians will be breeding, given the hydrologic fluctuation that can occur. This objective is intended to account for that dynamic by incorporating the wetland dynamic into the likelihood whereby the occupancy estimator will be conditional on those sites with a non-zero probability of breeding.

BASIC APPROACH:

We are currently working with the USGS and the Idaho State University to refine a protocol that will meet the needs of ARMI as well as the GRYN. ARMI has widely adopted use of occupancy as their basic approach. Occupancy provides a measure that: (1) explicitly enables estimation of local extinctions and colonization of sites; (2) takes into account detectability of individual species; (3) enables estimation of confidence intervals; (4) is comparable across sites; and (5) is becoming a widely accepted approach for reliable estimates of occupancy.

The general design will be a cluster design, with the primary design unit approximately equivalent to an 8th order. The size of these units resulted from an extensive collaborative effort with the USGS EROS Data Center as well as field testing as part of a pilot effort. All wetlands will be surveyed within each unit. The general suitability of hydrologic units—based on the quantity of NWI wetland types within each unit—will be used to define unequal sampling probabilities. This is necessary because most hydrologic units within the parks are of poor quality for amphibians. Thus, using an unequal inclusion probability will enable us to invest most of our resources in those units that are most important to amphibians.

The overall design will likely be modified for BICA because most of the suitable amphibian habitat is contained within a series of impounded wetlands. Monitoring in BICA will consist of targeted surveys conducted collaboratively with the Wyoming Game and Fish Commission.

Principal Investigators and NPS Lead:

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Development Schedule, Budget, and Expected Interim Products:

The GRYN recently hosted a small workshop to address several issues of concern. Participants included staff members from the GRYN, GRYN network parks, ARMI, University of Idaho, and the USGS-Patuxent Wildlife Research Center. Based on the outcome of the workshop and subsequent workshops, we modified the existing ARMI methods to an approach that will be consistent throughout the Rocky Mountains from Montana to Colorado. We have just completed field testing of those modifications in collaboration with ARMI during FY05, with an expectation for a full protocol ready for review in fall of 2005. We anticipate full implementation by spring of 2006. The total cost to NPS will be approximately \$35,000 per year with additional funds at least equivalent to the NPS contribution coming from USGS ARMI program.

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Protocol Development Summary

Protocol: Aridland Seeps and Springs

Parks Where Protocol Will Be Implemented: BICA

Justification/Issues Being Addressed:

Seeps and springs are often the only localized water source within a desert/arid environment during the drier periods of the year, since there are few perennial tributaries within the NRA. Also, Bighorn Lake (a reservoir behind Yellowtail Dam) is located within a deep canyon with vertical cliffs through much of the NRA and is difficult to access, and the water level is subject to tremendous variability depending on yearly and seasonal irrigation demands and on-going water rights disputes. Seeps and springs maintain the flow in many streams and in some cases are the sole sources for tributaries feeding Bighorn Lake. Plant and insect populations thrive in seeps and springs. By supporting the base of the food chain, seeps and springs indirectly support upland communities through trophic energy transfer. Some springs support known rare, endemic flora (e.g., *Sullivantia hapemanii* var. *hapemanii*) and possibly rare invertebrates. Other fauna are potentially strongly dependent on these scarce and vital water sources.

There are threats to seeps and springs within Bighorn Canyon that could reduce their potential to support wildlife, biodiversity, and streamflow. These threats include trampling and herbivory of vegetation and degradation of water quality by human visitors and ungulates (cattle and wild horses), and potential degradation of water quality and loss of water quantity through influence of industrial and agricultural activities and changes in water rights both inside and outside of the NRA on local and regional aquifers.

Of the three Greater Yellowstone Network units, Bighorn Canyon NRA is most susceptible to long-term climate changes affecting the primary water sources away from the mainstem of Bighorn River and Bighorn Lake behind Yellowtail Dam.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Specific monitoring questions are:

1. What are the current hydrological and ecological condition of the seeps and springs in BICA?
2. Which springs are affected by natural climatic changes or stochastic events vs. human-caused disturbance?

And more specifically:

3. Are there springs/seeps vulnerable to degradation from human activities both inside and outside the park?
4. Are the springs/seeps vulnerable to climatic changes?
5. Are there specific activities that degrade water quality, reduce water quantity (discharge) or change hydroperiod characteristics?

Specific monitoring objectives are:

Objective 1: Estimate discharge, variation in discharge, and change in discharge over time of seeps and springs within BICA, taking into account seasonal annual, and decadal variation.

Justification for this objective.--

Spring locations in BICA are documented on USGS topographic maps and in cultural references. However, spring ecosystems have not been described beyond the occurrence of a rare wetland plant—*Sullivantia hapemanii* var. *hapemanii*. Thus, baseline data are necessary to understand the current status of the resource and serve as a reference point for change detection. Discharge at the orifice is the first to respond to changes in climate, groundwater volume and groundwater flow.

Objective 2. Determine the status and change over time of water chemistry parameters at the orifice of seeps and springs within BICA including, but not limited to, conductivity, dissolved oxygen, pH, water temperature. Additional assessments of herbicides, fertilizers, pesticide usage, septic leach fields and chemical spills from machinery may be warranted.

Justification for this objective.--

Water quality at spring orifices is a product of the contributing groundwater environment and the influence of the surface environment. Changes in water quality at the orifice indicate alterations to the groundwater environment. Changes in groundwater flow paths through different rock strata may alter the pH, temperature, specific electrical conductivity, etc. Groundwater pollution will also influence water chemistry in various ways depending on the pollutants. In BICA, the recharge areas nearest the orifice are susceptible to herbicide, fertilizer, and pesticide usage, septic leach fields and chemical spills from machinery. Detecting changes in water quality at the orifice will alert BICA staff to consider management actions that alleviate threats to groundwater quality.

Once at the surface, water quality parameters change with distance from the orifice due to interactions with the surface environment (e.g., evaporation, soil chemistry, biological transformations). If discharge is stable, then water quality at a particular distance from the orifice remains relatively stable. Long-term exposure to a particular set of stable aquatic chemical conditions results in specialized, often endemic, macroinvertebrate and plant communities.

Objective 3. Determine the status and change over time of aquatic macroinvertebrate composition along the first 100 m of runout of seeps and springs within BICA.

Justification for this objective.--

Decreases in specialists and increases in generalist species often occur when variability in environmental conditions increases (Sada et al. 2005). Many spring species have narrow environmental ranges (specialists) and therefore are susceptible to changes in water chemistry and habitat quality. Aquatic macroinvertebrates in spring ecosystems appear to display species-specific responses to disturbance due to a high degree of endemism (Heino et al. 2003, Sada et al. 2005).

Objective 4: Estimate spatial extent and change in spatial extent over time of mesic vegetation along the first 100 m of runout of seeps and springs within BICA.

Justification for this objective.--

Changes in extent of spring wetlands and riparian areas along spring runout correspond to water flow changes whether natural (climate) or anthropogenic (water use). Lowered water tables, decreased flows and shorter flow duration result in smaller spring areas (Thompson et al. 2002). Because riparian and wetland plant communities vary with groundwater depth, changes in groundwater levels may result in shifts in community composition of spring ecosystems (Grootjans et al. 1988, Hendrickson and Minckley 1985). Numerous studies across the arid West have documented wetland and spring ecosystem shrinkage and losses in biodiversity due to groundwater depletion, regardless of cause.

Objective 5: Determine species composition and change in composition over time of vegetation along the first 100 m of runout of seeps and springs within BICA.

Justification for this objective.--

Decreases in specialists and increases in generalist species often occur when variability in environmental conditions increases (Sada et al. 2005). A decrease in spring-related biodiversity could be indicated by a corresponding increase in upland or introduced aquatic and riparian species. While water quality and aquatic macroinvertebrates respond to acute environmental changes, soil chemistry and spring vegetation composition appear to respond to sustained environmental changes. Monitoring soil conditions in spring systems is fairly destructive which makes it a less appropriate monitoring attribute. Changes in spring vegetation composition indicate potential long-term, if not permanent, damage to spring ecosystems with the least amount of impact to the system. This objective will also enable us to determine the extent of native vs non-native plant species changes in micro habitat diversity.

BASIC APPROACH:

Most spring and seep locations are known. A brief inventory to locate additional springs and seeps, especially along the canyon walls in the North District, has been undertaken. Threats to ecosystem functions of seeps and springs have been identified, including: long-term climate changes; groundwater withdrawals and additions of polluted water; additional or changing water rights on lands outside NRA boundary that are hydrologically connected to BICA seeps and springs; and effects of human and ungulate activities. Twenty-four springs were visited. Four springs are proposed as candidates for monitoring: one seep, one cattle-impaired spring, one pristine spring and one human-impacted spring. The overall sampling design will be developed cooperatively among the cooperators and Rob Bennetts. We will have alternative sampling design packages such that the costs and feasibility of implementation can be considered in light of trade-offs among exclusion of specific monitoring objectives, spatial or temporal extent of sites monitored and levels of precision or type II errors.

Field SOPs will be developed to identify changes in flow, water quality and aquatic and riparian vegetation, specific rare and/or sensitive plant species (and possibly specific invertebrates) associated with seeps and springs. Other standard operating procedures from protocols currently being developed will be incorporated as appropriate. These may include water quality and quantity SOPs from other spring/seep protocols (e.g., from NCPN), vegetation measurement SOPs from the landbird monitoring protocol and SOPs from the water chemistry protocol.

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Development Schedule, Budget and Expected Interim Products:

The sampling design and field data collection standard operating procedures as well as the data analysis and reporting protocols and final conceptual models will be completed by March 30, 2006.

The cost of the task agreement with the cooperators is \$57,500. There are also some costs associated with the salary for Elizabeth Crowe's time as NPS project technical representative and Cathie Jean and NPS Lead, which are difficult to forecast accurately.

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Protocol Development Summary

Protocol: Aridland Soil Structure and Stability

Parks Where Protocol Will Be Implemented: BICA

Justification/Issues Being Addressed:

National Park Service staff at is concerned about the impacts of grazing animal populations on the structure and function of soils in Bighorn Canyon NRA. This concern is based on personal observations in the field and on the results of the rangeland health assessment of the Pryor Mountain Wild Horse Range (PMWHR) (Natural Resources Conservation Service 2004). The NRCS states that rangeland within the NRA portion of the PMWHR is in an unhealthy condition, reflecting attributes of the soils and plant communities that “may not be able to recover from degradation without energy inputs, such as mechanical alteration” (Natural Resources Conservation Service 2004). These poor soil conditions include: severe erosion, excessive loss of biological soil crust cover, and high bare soil and erosion pavement cover. The NRCS also states that “conditions are right for an explosion of noxious weeds” (Natural Resources Conservation Service 2004).

In aridlands, overgrazing by ungulates can cause soil compaction, loss of vegetation, loss of biological soil crust cover and diminishment of microbial activity and can ultimately lead to soil erosion (Belnap et al. 2001, Evenari 1981, Lee 1981, Metting 1991). Compaction of soils decreases water infiltration as well as reducing soil aggregates and pore space, which are important for soil stability and soil biota habitat (Belnap 1995, Lee 1981, Whitford 2002). Changes in aboveground vegetative cover or composition may result in reduction of belowground phytomass. In aridland environments, which have sporadic temporal and spatial precipitation, underground phytomass reserves are important reservoirs that provide resilience in face of erratic primary production rates (Evenari 1981). Loss of vegetative cover also reduces soil nitrogen retention (Hooper and Vitousek 1997, Tilman et al. 1997) and results in loss of food supply for soil bioturbators, such as ants and termites, which are essential for maintaining macropores and channels for water infiltration and redistributing and decomposing organic matter (Lee 1981, MacKay 1991, Polis and Yamashita 1991, West 1981).

Nitrogen is a limiting nutrient in aridland systems (Whitford 2002). Loss of biological soil crusts disrupts nitrogen and carbon cycles in interspaces between vascular plants (Belnap 1995, Harper and Pendelton 1993, Metting 1991). Biological soil crusts increase soil surface stability through the entrapment and binding together of soil particles by polysaccharides exuded by cyanobacteria and green algae and by lichen and moss rhizines (Belnap et al. 2001, Metting 1991, St. Clair and Johansen 1993). Accordingly, loss of biological crust cover decreases surface soil stability (Whitford 2002). Biological crusts also improve water infiltration on fine-textured soils (Metting 1991).

This initial assessment by the NRCS provides not only justification but a baseline to begin monitoring. Through development of a long-term monitoring protocol, we can provide more precise monitoring of soil structural and functional conditions. Long-term monitoring sites, sampled on a regular basis can also demonstrate whether range conditions correlate with short-

term (5-10 year) climatic changes in the NRA. This monitoring may also allow for more precise correlation of soil characteristics with increases and decreases in ungulate population sizes. Other studies in the PMWHR on the effects of grazing ungulates on vegetation (Fahnestock and Detling 2000, Fahnestock and Detling 2000, Gerhardt 2000, Gerhardt and Detling 2000) were conducted over such short time periods that results are ambiguous at best, and the studies did not apply to soil structure and function. Additionally, there is a proposal to expand the PMWHR into two more areas in BICA, the Sorenson Extension and East Trail Creek, both of which are north of the current National Park Unit boundary and both of which are currently in good condition. Should this extension occur, it would be opportune to install baseline monitoring sites before horses start grazing these areas and monitor conditions over time to supply information for future management decisions about grazing in the extension.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:**Specific monitoring questions are:**

1. Are current soil structural and functional (nitrogen availability, soil moisture availability, wind and water erosion) attributes within the range of natural variability for different soil types?
2. Are there differences in soil structural and functional attributes and biological soil crust structure and composition in areas of ungulate grazing ranges compared to areas outside of ungulate grazing ranges? – see #1 above

Specific monitoring objectives are:

1. Determine the status and trend of unprotected bare soil, i.e., without biological crust cover or armoring by rocks, between vascular plants on each soil mapping unit paired both inside and outside of the PMWHR at three-year intervals.

BASIC APPROACH:

In FY2005 a literature review was completed, and threats and concerns were written. In July 2005 Dr. Jayne Belnap, world expert on biological soil crusts, who is helping to develop the soil monitoring protocols for the Northern Colorado Plateau and Southern Colorado Plateau Networks, joined GRYN and BICA staff on a two-day field trip to BICA to survey crusts in different soil mapping units inside and outside of the PMWHR and to discuss monitoring questions, objectives, sampling design and field methods.

NOTE: Communications Plan: This is an important Vital Sign to monitor, and we understand that it is a sensitive issue in that it involves the Pryor Mountain wild horse population. Thus, we will develop an appropriate communication plan along the same lines as the communication plan being developed for the Land use protocol.

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Development Schedule and Expected Interim Products:

- FY2005-2006 – planning phase; development of protocol
- FY2006 – pilot of sampling design and field procedures
- FY2007 – approval of final protocol and start implementation

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PROTOCOL DEVELOPMENT SUMMARY

Protocol: Climate

Parks Where Protocol will be Implemented: YELL, GRTE, BICA.

Justification/Issues being addressed: Climate is a primary driver of almost all physical and ecological processes in the Greater Yellowstone Network (GRYN). Climate controls ecosystem fluxes of energy and matter as well as the geomorphic and biogeochemical processes underlying the distribution and structure these ecosystems (Jacobson et al. 1997, Schlesinger 1997, Bonan 2002). The effects of climate are especially visible in the strong zonation and steep elevational gradients displayed by vegetation types in the Greater Yellowstone Ecosystem (GYE) (Despain 1990, Whitlock 1993). Conceptual system models for the GRYN have also emphasized the influence of climate on other vital signs in the region (NPS 2003). Because YELL and GRTE are major sources of runoff for the Columbia and Missouri River Basins, climate variability in the GRYN has profound implications across large portions of North America.

Proxy records from archives such as glacial ice, lake sediments, tree rings and fossil corals show that, in both the recent and distant past, the earth's climate has varied significantly over timescales from months to millennia. Studies using combinations of instrumental records and paleo-proxies confirm, however, that global climate has changed rapidly over the 20th century and that the speed of these changes exceeds that of most previous fluctuations (Mann et al. 1999, IPCC 2001, USGCRP 2003). Global surface temperatures, in particular, have risen by $0.6^{\circ}\text{C} \pm 0.2$ over the past century (IPCC 2001). Moreover, the bulk of scientific evidence indicates that this rise in global temperatures is related to human activities.

These global-scale changes will inevitably lead to significant alterations of Greater Yellowstone regional climate. Changing regional climate will, in turn, have a tremendous effect on natural systems in the GYE (Bartlein et al. 1997, Baron 2002, Wagner 2003). It is imperative that the parks of the GRYN have a climate monitoring system in place that allows for the detection and characterization of GYE climate change and provides climate data for use in monitoring and predicting the dynamics of other vital signs.

Weather and climate are also among the primary drivers of floods, fires and avalanches (NRC 1990, Singh 1996, Casale and Margotini 1999, Baker 2003). Timely and accurate weather and climate information can aid in predicting their occurrence and behavior, thus improving human safety and reducing negative economic impacts. Development and maintenance of weather and climate monitoring networks will provide invaluable information for the scientific study of these events.

Monitoring Questions Addressed by the Protocol:

Some of the specific monitoring questions that will be addressed by this protocol include:

- How does the climate of the Greater Yellowstone Ecosystem vary at different spatial and temporal scales relevant to the management of natural resources and the dynamics of other vital signs?

- Has the climate of the GYE changed significantly from that of past decades to centuries as a result of natural or anthropogenic forcing?
- Do these changes in climate warrant specific research or management actions to monitor or predict their effects on natural resources and other vital signs?

Specific Monitoring Objectives:

Objective 1: To measure precipitation and air temperature in the GRYN, including BICA, GRTE, YELL and surrounding areas.

Justification/Rationale for this objective: This objective will provide baseline data and continuously updated datasets to facilitate the detection of regional climatic change (both natural and human induced) and its effects on natural systems in the Greater Yellowstone Ecosystem (GYE) as a whole. Precipitation and temperature exert strong controls over almost all physical and ecological processes in the GRYN. Temperature and precipitation control ecosystem fluxes of energy and matter as well as the geomorphic and biogeochemical processes underlying the distribution and structure of these ecosystems (Jacobson et al. 1997, Schlesinger 1997, Bonan 2002). Because YELL and GRTE are major sources of runoff for downstream areas throughout North America, precipitation and temperature variability in the GRYN have profound implications outside the region as well.

Objective 2: To measure secondary climatic elements including wind speed/direction, relative humidity, soil temperatures and incoming solar radiation in the GRYN, including BICA, GRTE, YELL and surrounding areas.

Justification/Rational for this Objective: These data will complement information on temperature and precipitation gathered under Objective 1. Like the primary climatic elements (precipitation and temperature), wind, humidity, soil temperature and solar radiation exert strong controls over physical and ecological processes in the GRYN. These data are also tied to a large number of key GRYN vital signs. In the case of whitebark pine, for example, relative humidity and wind speed/direction are both key factors in controlling the spread of white pine blister rust (Kendall and Keane 2001). Wind and humidity influence fire behavior while soil temperatures and incoming solar radiation help control plant species distribution and ecosystem productivity.

BASIC APPROACH:

Unlike most vital signs, GRYN climate has been monitored continuously for over 100 yr. There is also a legacy network of monitoring stations maintained by a variety of state and federal agencies. Protocol development has focused on determining (1) if the legacy network provides adequate sampling of spatial and temporal variability in GRYN climate and (2) how best to address shortfalls in the current system.

Our basic approach involves a detailed analysis of existing climate monitoring stations in the GYE to determine if:

1. Current stations in the GRYN can adequately capture the key spatial and temporal components of climate variability in the region.

2. Strata of management interest or scientific importance are being adequately sampled.
3. The array of stations adequately provides data needed to understand and predict the dynamics of other vital signs in the GRYN.

Item #1 is being addressed using a combination of literature review and an examination of existing instrumental- and paleo-climate records for the GRYN. We are also examining sampling regimes and instrumentation at each site to determine if they meet National Weather Service surface observer guidelines (<http://www.nws.noaa.gov/directives/010/010.htm>), or if they must be updated to meet these standards.

Item #2 involves a series of geographic information systems (GIS) based analyses that will compare the locations of existing GYE climate stations (from Selkowitz 2003) against the vegetation and topography of the region.

Item #3 may also include a series of GIS-based analyses comparing station locations to key habitat types, populations of interest, sensitive ecosystems, etc., but will center on consultations with other cooperators and NPS personnel familiar with GRYN vital signs.

Efforts aimed at improving data transfer and archiving is also a key component of climate protocol development for the GRYN. Almost all high-quality climate data produced in the GRYN is now available via the Internet. These datasets, however, are hosted by a number of different agencies and navigating the vast amounts of available climate information can be a daunting and time-consuming task.

To maximize the usefulness and accessibility of GRYN climate data, we are exploring means to achieve:

1. Rapid data transfer.
2. Improved quality control and network-wide quality control standards.
3. Development of software and Web access that allows users to develop a mesoscale or synoptic view of current and past GRYN climate (*see* <http://www.mesonet.org/> *for examples*).

The GRYN and Big Sky Institute also recently conducted a workshop in conjunction with MTNCLIM 2005, a research conference aimed at understanding interactions between climate and ecosystems in western North America (www.fs.fed.us/pnw/mtnclim). This workshop focused on integrating climate monitoring in the GRYN with efforts from surrounding networks.

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Development Schedule, Budget, and Expected Interim Products: In June 2005 the network received a draft monitoring protocol from the cooperator. This protocol will be augmented with products derived from the Cooperative Agreement between NPS WASO and the Western Regional Climate Center which are expected in late 2006. The final protocol will be ready for peer review and full implementation in 2007.

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PROTOCOL DEVELOPMENT SUMMARY

Protocol: Integrated Water Quality

Parks Where Protocol will be Implemented: YELL, GRTE, BICA.

Justification/Issues being addressed: Water quality monitoring is a fundamental tool in the management of freshwater resources. The chemical, physical and biological health of waters is considered of national value and is protected by the Federal Water Pollution Control Act. This act is designed to ensure that Americans have clean water for domestic, agricultural, commercial and recreational uses. Water quality monitoring helps ensure that a water body is suitable for its determined use. It can also be used for protective purposes to prevent degradation or to upgrade conditions. Chemical and physical tests give information that is accurate only at the moment the sample is taken. Physicochemical measures have predominated North American aquatic bioassessments and monitoring programs despite the well-documented arguments that pollution assessment is primarily a biological problem. The use of macroinvertebrates as indicators of aquatic ecosystem health developed out of observations that specific taxa were restricted under certain environmental conditions (Richardson 1925, 1929 and Gauvin 1958). The presence of a mixed population of healthy aquatic insects usually indicates that the water quality has been good for some time. This then led to the development of a list of indicator organisms and the acceptance of using macroinvertebrates for use in water quality monitoring.

Water resources are especially important in the Greater Yellowstone Network (GRYN) because of the Outstanding National Resource Water designation for Yellowstone and Grand Teton National Parks. These important places are headwaters to the Yellowstone and Snake River watershed. Water resources also provide important public recreational opportunities in Bighorn Canyon NRA, critically important plant and wildlife habitat, and unique scenic vistas within all three network parks.

Aquatic resources across the GRYN face numerous and varied threats, including atmospheric deposition, altered hydrology, mining, agriculture, pollution from boats, non-native species, erosion, leaking underground storage tanks, improper sewage plant or drain field operations, and storm water runoff. Water quality monitoring to assess the effects of these threats has been underway for over 50 years, though not as a coordinated, comprehensive program focused on ecosystem health.

Specific Monitoring Questions and Objectives Addressed by the Protocol

Objective 1. Determine the status and trend of a primary set of water chemistry parameters including, but not limited to, conductivity, dissolved oxygen, pH, water temperature and discharge in perennial surface waters of all GRYN parks.

Justification/Rationale for this objective.-- The initial status and variation of core water quality parameters provides the background reference point to which all subsequent data will be compared. Although these data do not provide a measure of completely pristine conditions, they

do provide a measure of the status of aquatic systems at the start of the GRYN monitoring program.

Objective 2. Determine levels of substrate composition and embeddedness in perennial surface waters of GRYN parks.

Justification/Rationale for this objective.-- Sedimentation issues have been a concern in the parks for the past century. Sedimentation associated with grazing, construction (including roads), trail use and fire are of particular concern. Areas with steep slopes and geologically sensitive areas such as Mount Everts near Mammoth Hot Springs (YELL) and the Grand Canyon of the Yellowstone River (YELL) have been previously identified as areas of concern (www.nps.gov/yell/nature/nothernrange). Grazing of commercial livestock is of particular concern in GRTE. As of 2004, five ranches remain in the park with permits to graze 1,800 cows and horses on 36,000 acres of property (Smith 2004).

Objective 3. Determine the status and trend in benthic macroinvertebrate communities in flowing perennial in surface waters of GRYN.

Justification/Rationale for this objective.-- These data provide information on long-term trends in macroinvertebrate communities and will be used as an indicator of potential degradation. Changes in the macroinvertebrate community may indicate impacts (episodic events) on water quality missed in routine water chemistry monitoring. In addition, changes in the abundance or richness of macroinvertebrate may indicate changes in food-web dynamics that may impact both aquatic (fish) and terrestrial (birds, amphibians) ecosystems.

Objective 4. Determine the status and trend in the acid-neutralizing capacity of high-risk alpine lakes of the GRYN and estimate the rate at which water chemistry is changing over time in response to atmospheric deposition. Factors that determine high risk have been recently assessed through a complimentary research program that will enable us to identify this subset of lakes.

Justification/Rationale for this objective.-- Atmospheric deposition maps (for 1992 through 1999) of the Rocky Mountains show regions of high atmospheric deposition in the northern Rocky Mountains (Nanus and others 2003), including parts of Wyoming and Montana. High-elevation watersheds in the Rocky Mountains are particularly sensitive to the impacts of N-deposition because they are typically underlain by thin soils and resistant bedrock that provide little acid-neutralizing capacity, which makes the watersheds highly sensitive to chemical inputs (Williams and Tonnessen 2000, Clow and Sueker 2000, Nanus et al. 2003). Nitrogen deposition has been linked to high surface water nitrate levels, changes in zooplankton community composition (Barmuta et al. 1990), impacts on macroinvertebrate fauna (Kratz et al. 1994) and altered diatom composition (Williams and Tonnessen 2000, Lafrancois et al. 2003, Baron et al., 2000, Wolfe et al. 2001). Cutthroat and rainbow trout are particularly sensitive to acidic episodes that may result from nitrogen deposition (Baker et al. 1990). Current (2005) atmospheric deposition rates and proposed changes in atmospheric emissions, including increasing emissions from power plants and energy production near Grand Teton and Yellowstone, have the potential to further alter the chemistry of these aquatic ecosystems (Nanus et al. 2005).

Objective 5. Measure concentrations of polycyclic aromatic hydrocarbons (PAHs) and other constituents associated with two-stroke and four-stroke engines at targeted marinas within GRYN.

Justification/Rationale for this objective.-- Monitoring of surface waters will be designed to assess the impacts of two-stroke and four-stroke engines via direct deposition into the lakes (boating).

Objective 6. Determine input of nutrient enrichment and wastewater effluents through analysis of fecal coliform bacteria and macroinvertebrate communities at a small number of targeted sites of high concern within the GRYN.

Justification/Rationale for this objective.-- Surface waters located adjacent to or immediately downstream of old septic fields, park residential areas, heavily used backcountry sites, park lodging and dining areas may be susceptible to water quality impairments associated with waste water effluent.

Objective 7. To detect occurrence of aquatic invasive plant and animal species at select targeted locations most susceptible to initial invasion (marinas, areas of high fishing access, etc) with an emphasis on areas that coincide with water quality monitoring samples within GRYN.

Justification/Rationale for this objective.-- Detecting incipient populations of aquatic invasive species is crucial to preventing permanent establishment and/or spread. Eradication of an invader that is become established is rare (Mack and others 2000), so it is best to find and eliminate a species before it becomes established. Previous surveys have reported the presence of New Zealand mud snails in GRYN surface waters and initial investigations suggest the potential for others such as Zebra mussel (*Dreissena polymorpha*), Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*). These organisms are likely to have significant impacts on native vertebrate and invertebrate fauna and a monitoring program designed to detect the distribution and determine the trend in spatial extent and abundance is critical to park managers.

Basic Approach:

Our approach is intended to balance several conflicting considerations of cost, feasibility, statistical validity, preserving the integrity and continuity of previous data, and multiple users of water quality data. From purely a statistical standpoint, the broadest inference would be obtained using a probabilistic design (e.g., a Generalized Random Tessellation Stratified Survey Design [GRTS]); however, this would: (1) potentially decrease, at least initially, the integrity and continuity of existing fixed monitoring stations; (2) be prohibitively expensive given the difficulty of access to many parts of the GRYN; and (3) decrease its value for other vitals signs for which some fixed stations were located (e.g., geothermal monitoring). After considerable debate and discussion, the direction that we are now taking would:

1. maintain existing fixed stations as part of a split panel design (see below).

2. incorporate a component of probabilistic sampling within realistic costs.
3. incorporate a few targeted sites for specific threats (e.g., polycyclic aromatic hydrocarbons [PAHs]).

We will use a split panel design that partitions (splits) the panels (i.e., collection of sites sampled during a given year) into two or more revisit designs. Such an approach constitutes a compromise between emphasis on spatial and temporal variation. Typically, split panels entail an always visit design in combination with some other revisit design (e.g., repeating panel). The “always visit” design is the strongest for detecting temporal variation but is weak for detecting spatial variation since the same panels are visited on each occasion. Combining this with an alternative panel can strengthen detection of spatial variation.

Fixed monitoring sites were selected that target specific waters of concern and/or act as integrator sites (i.e., located at outlets of drainage basins with relatively homogeneous land use and physiographic conditions, intended to reflect conditions within that basin). As such, these are important data sources to the parks, which have placed high value on maintaining their continued monitoring. These sites also have sufficient access to enable feasible year-round monitoring. Thus, our intention is to maintain use of these sites in the context of the “always visit” component of the split panel design, where these sites are monitored every year and provide a temporal continuity that is used to help interpret sites selected through probability sample that have a repeating panel (see below).

The fixed sites would be augmented with additional sites selected through a probabilistic sample. These sites would be on a repeated panel design such that a subset of sites (probably within a given drainage basin) would be sampled in any given year. When all of the sites have been sampled (i.e., after a period of years), the sampling would then return to a repeat sampling of the first subset, and so on. This approach enables a sample of sites representing the spatial variation to be accumulated over several years (we are targeting 3-5). However, this type of panel structure can result in confounding of spatial and temporal variation, particularly when the samples within a given year are from the same basin. Given that logistical constraints of access precludes having the panels distributed throughout the parks within any given year, the fixed sites, which are monitored every year, will help to reduce the confounding of spatial and temporal variation.

The probabilistic approach that we will use will be the Generalized Random-Tessellation Stratified Design (GRTS [Stevens and Olsen 2004]), which is well suited to our needs. The GRTS design uses a hierarchical randomization process to achieve spatial balance across the region and resource and has good variance properties.

In addition to the design described above, we anticipate having a small set of targeted sites intended to assess specific threats. For example, sites in the vicinity of marinas will be targeted for monitoring polycyclic aromatic hydrocarbons and sites used for swimming may be targeted for fecal coliforms.

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The integrated water quality monitoring protocol is a collaborative effort among Rob Bennetts, who is lead on the sampling design, Rob Daley, who is lead on the data management, and park staff Susan O'Ney at GRTE, Cassity Bromley at BICA and Jeff Arnold at YELL.

Development Schedule, Budget, and Expected Interim Products:

The protocol narrative is a joint effort with help from the cooperator and network staff. The sampling design and protocol narrative will be completed and ready for peer review in FY06. Implementation will start in FY07.

The SOPs for this protocol were peer reviewed in 2005 as part of the review for the regulatory water quality plan, which covers objectives for 303(d) streams only (see the Regulatory Water Quality Protocol Development Summary for details). Changes specific to the integrated water quality protocol will be incorporated into the SOPs in FY06.

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Protocol Development Summary

Protocol: Invasive Plants

Parks Where Protocol Will Be Implemented: BICA, GRTE, YELL

Justification/Issues being addressed: Invasive exotic plants are a top priority vital sign for the Greater Yellowstone Network. There is a strong consensus among scientists around the world that, after habitat loss and landscape fragmentation, the second most important cause of biodiversity loss now and in the coming decades is invasion by alien plant, animal and other species (Allendorf and Lundquist 2003, Chornesky and Randall 2003, Walker and Steffen 1997). In all of the parks, invasive exotic plant species are a serious threat to natural and cultural resources. Yellowstone and Grand Teton are two of the more heavily visited national parks in the country and are visited by people from throughout the 50 states and the world, who bring a continuous influx of new species on their clothes and vehicles. Bighorn Canyon has fewer visitors but most of them come to the NRA for fishing and boating, and exotic aquatic species are spread even more quickly than terrestrial. Invasive exotic plants have replaced native vegetation in large areas of Grand Teton and Bighorn Canyon, are widespread in the Northern Range of Yellowstone, and present an ongoing threat of further displacement. This displacement affects not only native vegetative community structure, composition and succession but can also cause extirpation or extinction of endemic and/or endangered plant species (Mack et al. 2000, Walker and Smith 1997). Exotic plants that become invasive, aggressive and widespread create detrimental impacts to animal habitat and nutrition, soil nutrient cycling, and fire and flood processes in parks (DiTomaso 2000, Goodwin 1992, Mack et al. 2000). Park Service national management policy states that exotic species will not displace native species if displacement can be prevented (NPS 2001). In order to prevent this displacement, monitoring of new populations and established species is essential. In addition it is vital to monitor the effects of both the existence of exotic populations and the management of exotic populations on native species and ecosystems. Inventory or mapping of infestations has been completed for BICA, GRTE, and the Northern Range, along major roads and in some backcountry areas of YELL.

BASIC APPROACH:

There are four general areas of invasive plant monitoring that are addressed in this protocol: early detection, status and trend, effects of invasive plants on native vegetation and ecosystems, and restoration of native vegetation and ecosystems following control/treatment of invasive plants. Through the process of researching background material and writing threats and concerns for this vital sign as well as meeting with park staff about their needs and priorities, we are approaching these four areas of monitoring as described below.

Early Detection

FRONTCOUNTRY

The three park units in the GRYN have been conducting informal early detection surveys for species new to frontcountry areas of the parks in conjunction with their invasive plant control programs. The parks would like to standardize data management of the 11 standard NAWMA (North American Invasive Plant Mapping Standards) fields that are in the databases of the three park units in order to be able to share and consolidate information. Searching these frontcountry

areas has been found to be highly effective in detecting incipient populations of new species. GRYN staff will assist the parks in developing standard operating procedures (SOPs) for data collection, training of personnel and data management.

BACKCOUNTRY

For backcountry early detection monitoring GRYN staff will test procedures currently being developed by USGS researchers in various parks and I&M networks throughout the country. These procedures will be available in 2007. If these procedures are found to be practical for use in the GRYN park units, staff will develop SOPs for backcountry early detection monitoring in 2007-2008.

Status and Trend

Status and trend monitoring of invasive species will emphasize Priority 1-3 species (see below) and will likely be conducted by park staff. The GRYN will develop the SOPs and assist staff in initial implementation.

Effects of Invasive Plants on Native Vegetation and Ecosystems

GRYN staff will develop SOPs and conduct monitoring of the effects of invasive exotic plant populations on the native plant communities and ecosystems. This monitoring will emphasize Priority 4 species (see table below for definition of priority levels), which are so widespread in the parks that they are no longer considered treatable but are thought to have serious impacts on resources.

Restoration of Native Vegetation and Ecosystems Following Treatment/Control of Invasive Plants

GRYN staff will develop SOPs and conduct monitoring on the restoration of native plant communities and ecosystems following treatment/control of invasive plants.

A list of invasive exotic plants has been compiled for the three parks and a network classification of priorities for species has been created based on individual park prioritization categories (Table 1). These priority categories, based primarily on need for and ability to control populations, have been applied to specific monitoring objectives as shown below. The priority classifications will be updated over time as population demographics of established species and management priorities change and as new species arrive in the parks. If necessary, classifications will also be revised to reflect monitoring priorities rather than primarily control priorities.

We are currently developing a matrix of the 125 prioritized invasive exotic species on: phenology; demographics; general growth characteristics; reproduction; habitat affinities; tolerances; invasiveness; documented effects on native vegetation, nutrient cycling, soil biota, and higher trophic levels; and successful or recommended monitoring methods. This matrix will be used to develop final specific monitoring objectives. Currently, we have draft general objectives (see below) that will potentially apply to specific species in specific habitats or targeted sites in the parks.

Researchers at Montana State University are currently refining monitoring methodologies for tracking the changes in density and spread of invasive species (especially those that grow in definable patches, such as smooth brome) on national forest land north of Yellowstone National

Park. A main focus of their research is to determine the difference in invasiveness of a given species in different habitats. We will work as closely as possible with the researchers and YELL park staff to coordinate with and complement (rather than overlap) these efforts.

Monitoring of all important invasive plant species may be costly, especially in terms of field data collection. We will develop a set of sampling designs to answer different monitoring objectives that can be evaluated in terms of cost and feasibility and that will offer trade-offs in levels of precision or type II error rates.

Table 1. Definitions for GRYN Prioritization of Invasive Species

Watch List (WL): Exotic species not documented/established in the park(s).
Priority 1: Species that have produced seed in the park, but populations are small and limited in number. These species have a high probability for eradication with continued annual monitoring and treatment. They are also the most cost effective species to control. SMALL POPULATIONS, CONTROLLABLE
Priority 2: Species that are invasive and aggressive and capable of rapid spread within the parks. Most are confined to relatively small localized areas. These species are capable of disrupting or displacing native plants. Many of these species are well established in the park, but aggressive control can be effective by limiting the spread. Containment will be the primary goal for these species with eradication as a secondary goal. Individual plants or small infestations away from core infestation areas will be a high priority for aggressive control. AGGRESSIVE INVADERS, CONTROLLABLE
Priority 3: Species that are invasive but less aggressive and less capable of displacing native species. They are undesirable, but not necessarily as invasive as Priority 2 species. Control actions have a greater chance of containing or eradicating the populations. LESS AGGRESSIVE, CONTROLLABLE
Priority 4: Aggressive exotics that are dispersed over large areas of the parks and have deleterious effects on the park ecosystem. Control efforts are likely to be ineffective and costly and have lower probability of reducing, containing, or eradicating populations. However, work may be done to confine the spread of these plants in sensitive areas. These species may be treated with other treatment activities (i.e., roadside treatments, vegetation restoration work) but will not be aggressively treated until more feasible methods are found and approved. Biological controls will be utilized when available to reduce populations. Monitoring would be beneficial, but will come after Priorities 1 and 2. AGGRESSIVE, WIDESPREAD, (CURRENTLY) NOT CONTROLLABLE EXCEPT IN LOCALIZED AREAS
Priority 5: Exotics, for which little or no control efforts are foreseen. Even though many of these plants displace native vegetation, control of high priority species takes precedence. Limited monitoring actions may be undertaken. Approximately 138 species fall into this category. None of the plants in this category are listed as noxious by the surrounding states. ???
Priority 6: New species that have been found during inventory efforts throughout the park. Species are non-native, escaped ornamentals about which little is known. ???

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Monitoring questions are:

1. Where are new populations of invasive exotic plant species being established?
2. In which habitats of our network parks are these species invasive?
3. How can we monitor invasive plants to ensure that our currently known weed-free areas, especially in habitats that are rare, sensitive or of particularly high value, remain in that condition?
4. What is the status and trend of existing populations of invasive species of interest, including species being actively treated and those that are currently considered beyond control?
5. What effects are existing populations of invasive plant species having on native vegetation and ecosystems?
6. What effect is the management of exotic plant species having on restoration of native vegetation and ecosystems?

Current **DRAFT** general monitoring objectives are:

(NOTE!!: background work is still ongoing that will be used in refining monitoring objectives and making them specific to individual species and locations, i.e. inferential populations will be defined):

1. **Management Objective:** Prevent the establishment of viable populations of invasive exotic plants new to the parks (Watch list species).

Monitoring Objective: Detect occurrences of invasive exotic plants new to the parks before they become viable populations. Until USGS protocols are available to test in backcountry areas, this objective will be applied primarily to roads, developed sites and easily accessible areas of the parks, i.e. frontcountry areas.

2. **Management Objective:** Prevent the establishment of viable populations of invasive exotic plants (Priorities 1-3) in weed-free zones of the parks.

Monitoring Objective: Detect occurrences of Priority 1-3 invasive exotic plants in weed-free zones of the park before they become viable populations.

Justification/Rationale for Objectives 1 and 2.--

Detecting infestations as soon as possible is crucial to preventing establishment or allowing invasion to begin. Eradication of an invader that has become established is rare (Mack et al. 2000), so it is best to find and eliminate a species before it becomes established. In addition, the costs associated with controlling an invasive species escalate as it becomes more widely distributed (McNeely et al. 2001). Propagule pressure is very important to the success of an exotic plant becoming established and invasive (Allendorf and Lundquist 2003, Colautti and MacIsaac 2004, D'Antonio and Vitousek 1992, Williamson 1996). Propagule pressure comprises not only the number of seeds or regenerative asexual parts that a species produces, but also the number of establishment sites of a species. The more infestation sites or invasion foci a species has, the greater are its chances of successful establishment (Moody and Mack 1988). Also, the lag time for a given species to become invasive in an area is unknown, and there is no way to predict the outcome of any particular introduction of an exotic species (Lodge 1993). No successful set of characteristics to predict invasibility has been determined (Rejmánek and Richardson 1996, Williamson 1996). All of these reasons demonstrate the importance of finding and eliminating an exotic species as soon as possible after its arrival in an area.

3. **Management Objective:** Allow no establishment of viable populations of Priority 1-3 invasive species outside of control boundaries.

Monitoring Objective: Determine status and trend of Priority 1-3 invasive exotic plants outside of control boundaries at 5 year intervals.

4. **Management Objective:** Observe status and trend of selected Priority 4 & 5 invasive species throughout the parks in order to inform management.

Monitoring Objective: Determine distribution and abundance of Priority 4 & 5 invasive species at 5 year intervals.

Justification/Rationale for Objectives 3 & 4.--

Park weed management staff need information on the status of existing populations of invasive plants in order to prioritize yearly control efforts as well as to evaluate the success of containment of designated species. For some Priority 1-3 species control area polygons have been established within park boundaries. Management staff are less concerned with increases in abundances of species within these control areas than with establishment of species outside of control area boundaries. Control areas are specific to individual species and do not correspond to completely weed-free zones (see above). For example, Dalmation toadflax may have a 5 mi² control area in the vicinity of the Mammoth terraces in the northern range of YELL. The rest of the Northern Range is not weed-free but is outside of the Dalmation toadflax control area and may be targeted for status and trend monitoring for this species. For species that are widespread and untreated (Priority 4 & 5), no information is available on their population status. It may be that once a certain threshold of invasion pressure is exceeded, the whole structure of the native vegetative community collapses (Parker et al. 1999). Although traditional control efforts are not feasible for these species, information about their rates of spread and total coverage within the parks is potentially important information for management of threatened, endangered or sensitive plants, wildlife populations and fires.

5. **Management Objective:** Maintain the current native plant community and ecosystem attributes (e.g., frequency and cover of native plants, forage, habitat, soil stability and primary productivity) at 80-100% of levels associated with habitat types not infested with invasive exotic plants.

Monitoring Objective: Determine status and trend of selected native plant community (e.g., frequency and cover of key native plants) and ecosystem attributes (e.g., forage, wildlife habitat, soil stability, primary productivity) at locations (e.g., in targeted habitats) infested with one or more specified Priority 4 invasive plant species in comparison to comparable sites not infested with invasive plant species at five year intervals.

Justification/Rationale for Objective 5:

Very few studies have been conducted that address community-level consequences of invasion by exotic species (Woods 1997). From these few studies, however, plant invaders have been found to completely alter nutrient cycling, disturbance regimes, hydrology and energy budgets and can greatly diminish the abundance or survival of native species (D'Antonio and Vitousek 1992, Ehrenfeld 2004, Mack et al. 2000, Walker and Smith 1997, Woods 1997). In addition, primary productivity can be diminished by invasive plants and subsequently affect, for example, grassland forage for grazing animals (Walker and Smith 1997). Although we have little information specifically documenting the effects of the majority of invasive exotic species found in the GRYN park units, we expect these species to have moderate to substantial undesirable effects on native vegetation and other ecosystem components and processes. Priority 4 species are targeted for these objectives because most of them are not being treated or controlled by

park staff, except in some localized areas, and there is concern about their effects on native vegetation and ecosystems within the parks. Also, most of these species are not listed as noxious on state weed lists, are not researched as thoroughly as Priority 1-3 species. Noxious weed status is granted to invasive plant species that pose a threat to agricultural systems rather than to natural resources and natural ecosystems. Priority 4 species may pose a much greater threat to park resources than higher priority species. Without quantitative data, however, park staff cannot divert attention and request management funding to address these species.

6. **Management Objective:** Return native plant community and ecosystem attributes (e.g., frequency and cover of native plants, forage, habitat, soil stability and primary productivity) to levels associated with habitat types not infested with invasive exotic plants. To have statistically significant improvement in these ecosystem properties within three years of treatment.

Monitoring Objective: Determine status and trend of native plant community (e.g., frequency and cover of key native plants) and ecosystem attributes (e.g., forage, habitat, soil stability, primary productivity) of selected sites where invasive species have been treated/controlled in comparison to habitat types not infested with invasive exotic plants at five-year intervals.

Justification/Rationale for Objective 6:

Eradication of an exotic species can have unintended negative impacts on the ecosystem, including invasion by other exotic plant species or loss of critical habitat for a rare native species (Zavaleta et al. 2001). On the other hand, eradication of exotic species often allows native vegetation to become reestablished on the available site. Treatment of invasive plant species is not successful unless native ecosystem properties have returned to the functional level of similar uninvaded ecosystems.

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Development Schedule and Expected Interim Products:

In FY06, the GRYN will determine the primary focus of the invasive plant monitoring program and revise monitoring objectives accordingly. The schedule for protocol development and implementation is timed to take advantage of products developed by the national program, other networks and regions that have on-going task agreements for backcountry early detection monitoring etc. In FY06 the GRYN will work with the network parks to formalize the front country early detection 'repeat inventories' by developing protocols for data collection, data management and reporting for use by the parks.

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Protocol Development Summary

Protocol: Landbirds

Parks Where Protocol will be Implemented: YELL, GRTE, BICA

Justification/Issues being addressed: This vital sign measures the distribution and abundance of landbirds, other than those selected as "sensitive species".

Protection of native species and their habitats is one of the primary challenges outlined in the NPS Natural Resource Challenge (National Park Service 1999). The National Park Service Inventory and Monitoring Guidelines (NPS-75) further state that "...preserving the natural resources (and natural processes) in the national parks may be the most important legacy the Park Service can provide American conservation." Thus, monitoring the composition of native communities of concern and the changes occurring within and among these communities is essential to meeting our Natural Resource Challenge.

Because of the large number of habitat types within the Greater Yellowstone Network (GRYN) and the enormous variability within these habitat types, our initial efforts on landbirds will focus on estimating the status and trends of landbirds within four habitats (communities) of concern: alpine, aspen, shrub steppe (sage), and riparian. Although the overall objectives will be very similar among these habitat types, there may be subtle differences in the secondary objectives that reflect the potential threats to each of these habitat types.

Our specific monitoring objectives are intended to answer the following general question: Are there observable changes in the native bird communities for each of four habitats of concern that would indicate a systematic changes in abundance or distribution within these habitats that is indicative of that habitat becoming less suitable for persistence of the native avian fauna associated with these communities?

Monitoring Questions Addressed by the Protocol:

Some of the specific monitoring questions that will be addressed by this protocol include:

- What is the proportion of sites within a given habitat of concern that is occupied by the obligate species of that habitat?
- What is the density and variation in density of obligate species within each of four habitats of concern?
- Are there systematic changes in community composition within the four habitats of concern that would be indicative of that habitat becoming less suitable for persistence of the native avian fauna associated with these communities?

Specific Monitoring Objectives:

Note: The scope of inference for all objectives will be four habitats of concern (alpine, aspen, riparian, and sage-shrub steppe), where they occur within the GRYN. Details of how these habitats are defined are provided in the full protocol.

Objective 1. To estimate the proportion of sites occupied (MacKenzie et al. 2002) in habitats of concern in BICA, GRTE, and YELL and to estimate the changes in occupancy over time. Although we will estimate occupancy and changes in occupancy for all species with sufficient data, our emphasis will be species identified as dependent on or obligates of the particular habitat of concern (see protocol for details).

Justification/Rationale for this objective.-- Changes in distribution are often used as indicators of environmental quality. Estimates of occupancy are a direct measure of distribution and the corresponding measures of local extinction and colonization of sites can provide valuable information as to the thresholds of that quality.

Objective 2. To estimate the abundance (density) of birds in habitats of concern in BICA, GRTE, and YELL and to estimate the changes in abundance over time.

Justification/Rationale for this objective.-- Population dynamics, hence changes in abundance, frequently depend on environmental factors (Buckland et al. 2001); thus, they are often used as indicators of environmental quality. Further, Bock and Jones (2004) recently examined 109 reported cases of 67 species in North America and Europe and concluded that in most cases density was a reliable indicator of habitat quality.

Objective 3. To estimate community composition and associated parameters of landbirds in habitats of concern in BICA, GRTE, and YELL and to estimate trends in these parameters over time. Specific parameters to be estimated include, but are not limited to, species richness and relative species richness (e.g., richness of native to exotic species).

Justification/Rationale for this objective.-- Biodiversity is “central to the productivity and sustainability of the earth’s ecosystems” (Christensen et al. 1996), and preserving natural abundances and diversity of native plants and animals is one of the general principles guiding the management of biological resources in our national parks (NPS 2000).

BASIC APPROACH:

The general sampling for each of our objectives would be essentially the same, and these objectives would be reflected in different ways of analyzing the resulting data. Our sampling approach is based on distance-based “point transects” (Buckland et al. 1993, 2001) with some minor refinements in the design to facilitate estimation of some parameters. Although in some cases we may use actual line transects, the use of points allows us to measure some site-specific covariates that may be useful in interpreting the results.

Our measure of changes in distribution would be based on the proportion of sites occupied (MacKenzie et al. 2002). This measure: (1) explicitly enables estimation of local extinctions and colonization (MacKenzie et al. 2003); (2) takes into account detectability of individual species (MacKenzie and Kendall 2002); (3) enables estimation of confidence intervals; (4) is comparable across sites; and (5) is becoming a widely accepted approach for reliable estimates of occupancy.

Estimates of density, based on distance sampling, explicitly account for detectability of

individuals of a species through estimation of a detection function, given certain assumptions detailed in Buckland et al. (2001).

Estimates of community-level parameters (e.g., species richness and relative species richness) will be based on the approach developed by Boulinier et al. (1998) and Nichols et al. (1998) using program COMDYN (Hines et al. 1999). As for the other parameters, this approach explicitly takes into account species detectability.

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Development Schedule, Budget, and Expected Interim Products:

The general field methods and sampling design have been developed and will be compatible with the Rocky Mountain Bird Observatory (RMBO) protocol. We also recently completed a field testing of methods at GRTE and anticipate a full advanced draft of our protocol by late fall 2005. We anticipate full implementation by spring of 2006. The budget will depend on final details of the sampling design, but is expected to cost approximately \$50k for full implementation of this program.

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Protocol Development Summary

Protocol: Land use

Parks Where Protocol Will Be Implemented: YELL, GRTE, BICA

Justification/Issues being addressed: Land-use activities surrounding park borders can significantly influence the status of ecological condition and functioning within parks. The Greater Yellowstone Network (GRYN) has identified land use change as a top priority vital sign for defining ecosystem health within parks. Long-term monitoring of land-use activities surrounding parks of the GRYN will provide information on trends in land-use and land-cover change and allow for analyses that quantify potential consequences for park resources. This will provide managers with the scientific background for incorporating the consequences of surrounding land-use activities into park management decisions.

Specific monitoring objectives will answer the following questions: How is land use changing around parks, and how do these changes impact park ecosystem components and processes?

Monitoring Questions Addressed by the Protocol:

The primary monitoring questions that will be addressed by this protocol are:

- What is the extent of different land-use activities, and how is this changing over time?

Specific Monitoring Objectives:

Objective 1 – To determine the density and location of homes on private and public lands within BICA, GRTE, and YELL, 20 counties comprising the Greater Yellowstone Ecosystem (Rasker 1991), and two additional counties surrounding BICA.

Justification/Rationale for this objective. -- Housing density can have significant ecological impacts, including: general loss of habitat, loss of unique habitat components, barriers to animal movements, increased disturbance and altered hydrologic regimes (including changes in water quantity and quality). Thus, understanding changes in housing density surrounding parks may have important implications for the functioning of the parks.

Objective 2 – To determine the number, length and type (i.e. size) of roads within 22 counties within and surrounding the GRYN, as well as measure changes in the existence and characteristics of roads over time.

Justification/Rationale for this objective. -- Roads can have significant ecological impacts, including: the fragmentation of habitats, direct wildlife mortality from collisions with cars, and increased accessibility to backcountry areas resulting in higher levels of human disturbance in remote areas. Therefore, quantifying the extent and characteristics of roads, and monitoring change over time, is relevant for considering the ecological impacts of land-use change on ecological condition of parks.

Objective 3 – To determine the distribution, area, and type of agricultural habitats within 22 counties within and surrounding the GRYN, as well as measure changes to those attributes over time.

Justification/Rationale for this objective. -- Although the effects of agriculture may be less intensive than some other types of land use (e.g., urban development), agriculture also can have significant ecological impacts, including: the conversion of important habitats, increased disturbance and altered hydrologic regimes (including changes in water quantity and quality). Further, the area of land surface altered by agriculture likely exceeds that of more intensive development. Thus, understanding changes in agriculture surrounding parks may have important implications for the functioning of the parks.

Objective 4 – To determine the distribution and area of major land use changes that can be detected using remotely sensed data (Landsat) within 22 counties within and surrounding the GRYN. This objective would not target successional vegetation changes; rather major abrupt changes such as clearcuts, new developments and fires.

Justification/Rationale for this objective. – Some major land use changes are not recorded through government records used for housing, roads or agricultural. This objective would target only the most major and abrupt changes that could be detected through coarse scale image classification (e.g., clearcuts, new developments and fires).

Basic Approach:

The general approach for this vital sign will be to use land-cover maps derived from remotely sensed data to determine the general distribution of housing and agricultural development. These maps will provide only the crude distribution of primary land-use types equivalent to approximately the Level I features of the Anderson et al. (1976) classification scheme or the land cover classes used by the National Land-Cover Database (NLCD) (Vogelmann et al. 1998, Homer et al. 2004). Such maps will not provide sufficient accuracy or detail for monitoring change over time (Jones and Hansen 2005). As such, these data will be augmented with ancillary data (described below) for more detailed metrics.

Housing density- Ancillary data used to derive housing densities have been described in detail by Hernandez (2004) and Jones and Hansen (2005) and are derived from county tax-assessor offices, state Departments of Revenue, and the U.S. Census Bureau (USCB). Because of differences among states and/or counties in data storage and distribution, some compilation, processing and merging will be necessary. The scale of these data will likely be in 1 mi² units identified by township/range/section (TRS). The TRS field will also provide a basis for joining states, counties, etc. for this attribute. We anticipate compiling data on housing density and assessing change of this attribute every five years.

Roads- As part of the decennial census, the USCB also distributes TIGER/Line files which include geographic information about roads. This is the most extensive and reliable census of roads within the GRYN study area, and the only source for which roads are updated on a regular basis. TIGER files are used in conjunction with a Geographical Information System (GIS), so

that roads can be mapped at 1:100,000 scale across the entire study area. Roads are classified into five categories, including interstates, state and county highways, local roads, and four-wheel drive logging roads. We anticipate compiling data on roads and assessing change of this attribute every ten years.

Agriculture- The USDA NASS compiles a county-level census of agriculture every five years, and distributes this agricultural information for free on its Web site. The census of agriculture data quantifies most of the agriculture monitoring classes, including total agriculture, irrigated and non-irrigated cropland including hay and other crops, and irrigated and non-irrigated pastureland. Data for irrigated and non-irrigated cropland and pastureland classes are distributed separately from data for total agriculture. These two data sources can be manipulated and merged to create one database containing data for each county. These data can then be spatially referenced by linking to a county basemap. The final map quantifies all levels of agricultural classes for each of the counties within the GRYN study area. We anticipate completing an updated map of agriculture and assessment of change every five years.

Other Major Land use Changes- This objective would be accomplished through comparison of Landsat imagery from one time period to another. The specific details/protocol has not yet been developed, but the methodology would likely be similar to other ratio techniques that are used for vegetation indices or fire severity indices.

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Development Schedule and Expected Interim Products:

A draft protocol, including SOPs, was submitted to the GRYN in January, 2005 and included a literature review of land-use change in the region surrounding GRYN parks, conceptual models identifying indicators of land-use change, and draft monitoring objectives. Monitoring objectives were subsequently revised after discussions with park and network personnel. This protocol from our cooperator needs to be augmented with information from the network on data management, reporting, etc. We anticipate a complete protocol ready for review in 2006.

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Protocol Development Summary

Protocol: Regulatory Water Quality

Parks Where Protocol will be Implemented: YELL, BICA

Justification/Issues being addressed: Regulatory water quality monitoring is being conducted in response to the requirements of the Clean Water Act (CWA) and the direction of the vital signs monitoring program. The CWA requires states to adopt standards for the protection of surface-water quality. Both Montana and Wyoming have established specific water-quality standards identifying what concentrations of chemical pollutants are allowable in their waters. Water-quality standards themselves consist of two parts: a specific desired use appropriate to the waterbody, termed a designated use, and a criterion that can be measured to establish whether the designated use is being achieved. A waterbody is considered to be impaired when water quality monitoring data reveal changes to natural conditions that exceed those allowed by state standards. The CWA also requires states to submit a listing (commonly referred to as the 303[d] list) of impaired waters to the Environmental Protection Agency (EPA) every other year.

The vital signs monitoring program views the monitoring of state identified impaired waters as fulfilling the fundamental requirement of Goal 1a4 of the National Park Service (NPS) Strategic Plan (NPS 2001), and partially fulfilling the requirements of the Government Performance and Results Act (GPRA) which mandates that federal agencies (federally funded programs) focus on “measurable or quantifiable” results for reporting to Congress. In contrast to several other vital signs components, the CWA provides one recognized means (by formal statute and state-developed numeric criteria and narrative standards) for the NPS to broadly measure improvement, or further degradation, of 303(d)-listed water resources and synthesize that information in reports to Congress (NPS 2003).

Four waterbodies in the Greater Yellowstone Network (GRYN) have been identified by the states of Montana and Wyoming (in response to the CWA) as being impaired and appear on their respective 303(d) lists. Causes for listing include: fecal coliforms, nitrogen, dewatering and metal contamination. The parameters to be monitored are dependent not only on the cause for listing, but also upon the specific criteria that each state uses to define the use categories or classes of its surface waters.

Monitoring Questions Addressed by the Protocol:

The development of measurable objectives is a critical element of any monitoring protocol. Regulatory monitoring (i.e., monitoring conducted under the provisions of the CWA) is intended to determine whether certain chemical or biological parameters meet state standards. The parameters chosen for monitoring are those found to be outside state standards and are the reasons for listing as 303(d) impaired by either the state of Montana or Wyoming. By answering the general question “Does parameter “X” exceed state standards?” the GRYN will:

1. Determine whether the overall goal of improved water quality is being achieved; and

2. Help gather information on the pollutants that exceed standards to assist the park and the state in designing specific pollution prevention or remediation programs through total maximum daily loads.

These objectives specifically cover streams that are currently listed by the state as 303(d). Montana and Wyoming update their list of impaired river and streams (303(d)) every two years. Bighorn Lake is scheduled to be assessed by the state of Montana in 2005. GRYN will keep apprised of state 303(d) status; if the status of streams in the network change and new streams are listed, additional objectives will need to be developed.

Specific monitoring objectives

Based on Wyoming standards for fecal coliforms (WY-DEQ 2001) (and anticipated standard for *Escherichia coli* [*E. coli*]), the regulatory monitoring objectives for the impaired portion of the Shoshone River are:

- 1a) Determine fecal coliform concentrations at the sampling location Shoshone River at Kane. Compare analytical results to the state standard: the geometric mean of 200 organisms per 100 milliliters based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period.
- 1b) Determine *E. coli* concentrations at the sampling location Shoshone River at Kane. Compare analytical results to the state standard: the geometric mean of 126 organisms per 100 mL based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period.

Based on Montana standards for nitrogen and the required documentation for “partially supporting” waters, the regulatory monitoring objective for the impaired portion of the Bighorn River are as follows:

- 2a) Determine nitrate concentrations at the sampling location Bighorn River near St. Xavier. Compare analytical results to the state standard: 10,000 µg/L as the geometric mean of monthly measurements.
- 2b) Determine the natural range of variability of nitrate concentrations at the sampling location Bighorn River near Xavier, based on monthly measurements.
- 2c) Determine the MT impairment score for macroinvertebrates (based on taxa richness, EPT richness, biotic index, % dominant taxon, % collectors, % EPT, Shannon diversity, % scrapers+shredders, #predator taxa and % multivoltine) at the sampling location bighorn River near St. Xavier. Compare to the state standard of between 0.75 – 1.00 for fully supporting waterbodies.

Sampling recommendations for Soda Butte Creek are based on a synoptic study conducted by Knauf and Williams (2004). Sampling of invertebrates, total and dissolved trace metals, and trace metals in sediments will address concerns about metal contamination in Soda Butte Creek. Metals targeted for analyses include arsenic, copper, iron and selenium. Samples will be

collected twice a year. The first sampling event will occur during snowmelt, when the hydrograph for Soda Butte Creek is on the ascending limb. This sampling time was chosen because it is the time when flushing from the surrounding areas will occur, mobilizing metals that could enter Soda Butte Creek. For total and dissolved metals, morning and evening sample collection will catch any diurnal variation that might occur. The second sampling event will occur during baseflow in order to determine any chronic conditions. Care should be made to sample close to the same date(s) each year so that trends in the data can be determined.

- 3a) Determine levels of dissolved and total metals at the sampling location Soda Butte Creek at the park boundary, both in the morning and evening at snowmelt and baseflow. Compare analytical results with state chronic/acute standards of 340/150 µg/L for arsenic, 7.3/5.2 µg/L for copper, 1000/NA µg/L for iron, and 20/5 µg/L for selenium.
- 3b) Determine levels of metals in sediment at the sampling location Soda Butte Creek at the park boundary. Compare analytical results with the probable effect concentration (33 mg/kg for arsenic and 149 mg/kg for copper [EPA 2002]) at snowmelt and baseflow.
- 3c) Determine the diurnal variation of dissolved metals and total metals at the sampling location Soda Butte Creek at the park boundary, during snowmelt and baseflow.
- 3d) Determine the MT impairment score for macroinvertebrates (based on taxa richness, EPT richness, biotic index, % dominant taxon, % collectors, % EPT, Shannon diversity, % scrapers+shredders, #predator taxa and % multivoltine) at the sampling location Soda Butte Creek at the park boundary. Compare to the state standard of between 0.75 – 1.00 for fully supporting water bodies.

Table 1. Standards for total, dissolved and metals in sediments.

Parameter	MT Aquatic Life Standard (µg/L) (MT-DEQ 2002)		Probable Effect Concentration (EPA 2002)
	Chronic	Acute	
Arsenic	340	150	33 mg/kg
Copper	7.3@50 mg/L hardness	5.2@50 mg/L hardness	149 mg/kg
Iron	1000	n/a*	n/a*
Selenium	20	5	n/a*

*standard does not exist

Based on the Fish and Wildlife Service recommendation (1987) for minimum in-stream flow for Reese Creek, the regulatory monitoring objective for the impaired portion of Reese Creek is as follows:

- 4a) Measure discharge continuously at Reese Creek and compare with recommended minimum flows ($0.037\text{m}^3/\text{s}$ between April 15 and October 15).

BASIC APPROACH:

This monitoring protocol targets specific objectives related to 303(d) listed water bodies in the network. The network expects that many of the standard operating procedures developed for this protocol will also be used in the integrated water quality monitoring protocol.

Existing protocols or methods that are incorporated into the protocol:

The monitoring protocol for regulatory water quality monitoring has adapted and incorporated protocols from the following:

- American Public Health Association. 1998. Standard Methods for the Examination of Water and Wastewater. Twentieth Edition. American Public Health Association, Washington, D.C. 1268 pp.
- Montana Department of Environmental Quality. 1995. Non-Point Source Water Quality Standard Operating Procedures. <http://www.deq.state.mt.us/wqinfo/monitoring/SOP/sop.asp>
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- Texas Commission on Environmental Quality. 2003. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue. RG 415. Also available on-line at <http://www.tceq.state.tx.us/publications>. 198 p.
- U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at <http://pubs.water.usgs.gov/twri9A>
- Wyoming Department of Environmental Quality. 1999. Manual of Standard Operating Procedures for Sample Collection and Analysis. Water Quality Division, Watershed Program. Cheyenne, Wyoming. August 1999 and revisions.

In addition, EPA standard methods for analysis and sample preservation will be used by the GRYN, unless state standards dictate an alternate procedure.

The complete protocol consists of the protocol narrative, several appendices (which include field forms, maps, references, etc.), and eleven standard operating procedures (SOPs) which are summarized below.

Summary of Standard Operating Procedures

Initial Site Establishment – SOP#1

This SOP describes the process for formally establishing water quality sampling stations. Procedures include establishing NPSTORET project and station files, selecting a suitable location for collecting water quality samples, establishing a preliminary profile of field measurements, obtaining station coordinates, photographic documentation, creating field folders, installing a staff gage and establishing a rating curve.

Pre-Season Activities – SOP#2

This SOP provides a dozen or so steps that should be taken to prepare for the field season. Specific tasks include reading the entire protocol, obtaining required training, reviewing checklists, updating reference materials, updating field folders, testing equipment and preparing equipment blanks.

Safety and Health – SOP#3

The “Safety and Health SOP” provides safety checklists and forms for GRYN and contract personnel who are involved with field activities. This SOP is meant to be used in conjunction with more comprehensive manuals (cf. Lane and Fay 1997) that provide details on regulations and recommendations that apply to specific locales and field conditions. In addition, technicians are instructed to contact local park safety officers for information regarding local problems and issues such as bear safety, avalanches, West Nile virus, Lyme’s disease, and other location-specific issues.

Cleaning of Equipment for Water Quality Sampling – SOP#4

Standard procedures are described in this SOP for when, where and how to clean equipment and to collect equipment blanks and field blanks for quality control. Sections of this protocol have been adapted from Chapter A3 of the USGS National Field Manual (Wilde 2004). Also, equipment care after each stream visit is discussed, which includes general cleaning for biological contaminants including whirling disease spores.

Procedures for Collection of Required Field Parameters – SOP#5

This SOP focuses on the use of multi-parameter instruments and current velocity/flow meters for measuring the WRD required field parameters. Details include calibration of multi-parameter instruments, thermometers, thermistors and current velocity meters as well as the actual measurement procedures.

Procedures for Collection of Regulatory Parameters – SOP#6

Standard procedures for the collection of water quality samples for regulatory monitoring purposes in the GRYN are addressed in this protocol. This SOP describes sampling techniques such as preventing contamination, the use of disposable gloves, clean hands/dirty hands techniques, field rinsing of equipment, isokinetic sampling and filtration. Sample collection procedures for fecal coliforms, *E. coli*, nitrogen, total and dissolved metals, metals in sediment and two different procedures (one from Wyoming DEQ and one from Montana DEQ) for collection of benthic macroinvertebrates are described in detail. This SOP also provides instructions for sample preservation, labeling and packaging.

Quality Assurance/Quality Control Procedures – SOP#7

This SOP discusses aspects of the representativeness, comparability, completeness, precision, systematic error/bias and accuracy of the data to be collected for the regulatory water quality monitoring parameters in the GRYN. General data quality objectives (DQOs) for the GRYN are described. The use of quality control samples, such as blanks, duplicates and spikes is discussed with associated tables that illustrate the frequency, acceptable range and corrective actions for each QC sample. This SOP includes instructions for completing/maintaining instrument calibration log books, field log books and chain of custody forms. QA/QC procedures for data management, such as field data sheet review, electronic data entry, data archiving, data

verification, error correction procedures, data qualification codes and data validation are included in this protocol.

Data Management Procedures – SOP#8

This SOP outlines data stewardship responsibilities and lists specific instructions and references for managing data collected. The procedure focuses on the installation and configuration of NPSTORET (a standardized database application called the Water Quality Database Templates or NPSTORET) at network parks, data flow and submission of each park's master water quality data files to staff at NPS-WRD.

Data Analysis Procedures – SOP#9

This procedure provides guidelines for the analysis of the laboratory results from the regulatory water quality samples. The analyses of results from equipment blanks, descriptive statistics and trend analysis, calculating QA/QC and standard exceedances for fecal coliforms, E. coli, metals, macroinvertebrates, nitrate and discharge are described, as well as calculations for precision estimates.

Data Reporting Procedures – SOP#10

This procedure provides guidance for immediate reporting (i.e., when monitoring results show an exceedance of a state water quality standard) and for the preparation of annual reports. It includes a suggested report outline along with report review and distribution procedures. The information contained in this SOP was adapted for the GRYN from Peitz and Rowell (2004), Standard Operating Procedure #11, prepared for the Prairie Cluster Prototype Long-Term Ecological Monitoring Program.

Revising the Protocol – SOP#11

This SOP provides instructions for the use of the revision history log that lists all edits and amendments to a document since the original publication date. Information entered in the revision history log should be complete and concise. The table of changes in the narrative and each SOP tracks the original publication date and version, previous version date and number, date of revision, author(s) of revision, location of change by section and paragraph, description of change and the reason for change.

What is the basic methodological approach and sampling design?

Regulatory water quality monitoring for the GRYN will be conducted at fixed monitoring sites using an intermittent sampling scheme. Because state monitoring and assessment programs for water quality use this type of sampling design, it is important to continue this type of sampling to maintain data comparability. The sampling design follows the strategies described by the USGS National Water Quality Assessment (NAWQA) program (Shelton 1994) for basic and intensive fixed-site assessments. Basic fixed-site assessments characterize the spatial and temporal distribution of general water quality and constituent transport in relation to hydrologic conditions and contaminant sources. Intensive fixed site assessments characterize seasonal and short-term temporal variability of general water quality and constituent transport and determine the occurrence and seasonal patterns in the transport of contaminants (Shelton 1994).

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Development Schedule, Budget, and Expected Interim Products:

This protocol (O’Ney 2005) was completed and peer reviewed by NPS WRD personnel in 2005 and is available on the I&M website. Revisions (based on WRD comments) will be completed in early FY06. In June 2005 objectives 1-3 of this protocol were implemented. Implementation for objective #4 (Reese Creek) is planned for FY06. The network is presently populating the required fields of NPSTORET for the regulatory water quality monitoring project and associated stations. At present, the protocol is being implemented using park affiliated personnel. In FY06 the operational plans and budget will be combined with the integrated water quality

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Protocol Development Summary

Protocol: Streamflow

Parks Where Protocol will be Implemented: YELL, GRTE, BICA.

Justification/Issues being addressed: Streamflow is of such importance that the NPS Water Resources Division recognizes that “flow/discharge is a very important physical parameter of the water body that can strongly affect or show direct correlation to chemical parameters. For that reason, although not required, flow measurements are highly recommended” (Penoyer 2001, see also Irwin 2002). Streamflow at any point in time is an integration of the streamflow generation and routing mechanisms in a watershed. This integration also defines the water quality at that time, including land use activities, point source discharges and natural sources (NPS 1998). Thus streamflow measurement is an essential component of water quality monitoring.

The hydrology of rivers in the GYRN can change from direct human modification (e.g., impoundments, water abstraction) or via changes in climate (Meyer et al. 1999). Measurements of continuous discharge can help determine how water withdrawals and impoundments are influencing river and streamflow dynamics. Rivers can be altered hydrologically from dam operations (e.g., Snake River), which can in turn alter biotic assemblages (Stanford and Ward 1989). Water removal for irrigation can reduce instream flows and flood peaks in the summer, (e.g., Gros Ventre River, Bighorn River, Shoshone River, Spread Creek, Reese Creek) and may negatively impact fisheries populations (Mahoney 1987).

Climate change may alter stream hydrology (Poff 2002) which will affect all aspects of river ecosystem function (Meyer et al. 1999, Firth and Fisher 1992) ranging from food web interactions (Power et al. 1995) to nutrient cycling. Changes in baseflow characteristics may affect the following: balance of competitive, ruderal, and stress-tolerant organisms; creation of sites for plant colonization; structuring of aquatic ecosystems by abiotic vs. biotic factors; structuring of river channel morphology and physical habitat conditions; soil moisture stress in plants; dehydration in animals; anaerobic stress in plants; volume of nutrient exchanges between rivers and floodplains; duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments; distribution of plant communities in lakes, ponds, floodplains; duration of high flows for waste disposal, aeration of spawning beds in channel sediments. The timing of annual extreme water conditions (such as the date of maximum flow) may affect the following: compatibility with life cycles of organisms; predictability/avoidability of stress for organisms; access to special habitats during reproduction or to avoid predation; spawning cues for migratory fish; and evolution of life history strategies; behavioral mechanisms (The Nature Conservancy 2005).

Specific Monitoring Questions and Objectives Addressed by the Protocol: Specific monitoring objectives are being developed to answer the following broad question:

Are the magnitude, timing and duration of streamflow changing in the GRYN?

Objective 1.

Estimate trends in baseflow characteristics of rivers within or adjacent to the GRYN that are “permanently” gaged by the USGS.

Objective 2.

Estimate trends in the timing of annual extreme water conditions of rivers within or adjacent to the GRYN that are “permanently” gaged by the USGS.

Objective 3.

Compare annual hydrographs for the five most recent years of record of rivers within or adjacent to the GRYN that are “permanently” gaged by the USGS.

BASIC APPROACH:

This monitoring protocol will include the networks plans for gathering, storing, analyzing and reporting on streamflow in the GRYN. The GRYN will utilize the network of permanent streamflow (continuous discharge) gaging stations that are being monitored by the USGS National Stream Gaging Program. Currently streamflow is being monitored continuously by the USGS at the following locations:

Station_Name	USGS Station_ID	Period_of_Record
Madison River near West Yellowstone MT	06037500	1913-present
Yellowstone River at Yellowstone Lk Outlet YNP	06186500	1926-present
Soda Butte Cr nr Lamar Ranger Station YNP	06187950	1888-89; 1990-present
Lamar River nr Tower Falls Ranger Station YNP	06188000	1923-present
Yellowstone River at Corwin Springs MT	06190500	1889-1893; 1910-present
Gardner River near Mammoth YNP	06191000	1938-present
Firehole River near West Yellowstone MT	06036905	1983-1996 (discharge); 2002-present
Gibbon River at Madison Jct, YNP	06037100	2000-present
Boiling River at Mammoth, YNP	06190540	1988-1995; 2002-present
Soda Butte Cr at Park Bndry at Silver Gate	06187915	1999-present
Tantalus Creek at Norris junction, YNP	06039640	2004-present
Bighorn River at Kane, WY	06279500	1928-present
Bighorn River near St. Xavier, MT	06287000	1934-present
Shoshone River near Lovell, WY	06285100	1966-present
Snake River AB Jackson Lake t Flagg Ranch WY	13010065	1983 to present; prior to 1988 pub as 13010200
Snake River NR Moran WY	13011000	1903 to present
Pacific Creek at Moran WY	13011500	1906 to 1917; 1944 to 1975; 1978 to current year

Buffalo Fork AAB Lava Creek NR Moran WY	13011900	1965 to present
Gros Ventre River at Zenith WY	13015000	July-Sept. 1917 and 1918; October 1987 to present
Granite C AB Granite C Supplemental, NR Moose, WY	13016305	1995 to present
Snake River AT Moose, WY	13013650	1995 to present

Our primary goal is to connect park managers with available data by providing annual and synthesis reports on streamflow using these data.

The GRYN will analyze and interpret streamflow data through the use of the analysis program “Indicators of Hydrologic Alteration” or IHA. IHA is a software program that provides useful information for those trying to understand the hydrologic impacts of human activities. Over 1,000 water resource managers, hydrologists, ecologists, researchers and policy makers from around the world have used this program to assess how rivers, lakes and groundwater basins have been affected by human activities over time or to evaluate future water management scenarios. This program was developed by scientists at the Nature Conservancy to facilitate hydrologic analysis in an ecologically meaningful manner. This software program assesses 67 ecologically relevant statistics derived from daily hydrologic data. For instance, the IHA software can calculate the timing and maximum flow of each year’s largest flood or lowest flows, then calculates the mean and variance of these values over some period of time. Comparative analysis can then help statistically describe how these patterns have changed for a particular river or lake due to abrupt impacts such as dam construction or more gradual trends associated with land- and water-use changes.

Principal Investigators and NPS Lead:

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Development Schedule, Budget, and Expected Interim Products:

A protocol narrative (5-10 pages) and associated SOP for using the IHA will be completed, peer-reviewed and implemented in FY06 for targeted watersheds in the GRYN. This protocol is expected to be brief and should be relatively inexpensive to prepare.

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Protocol Development Summary

Protocol: Whitebark pine

Parks Where Protocol will be Implemented: YELL and GRTE, with the possibility of BICA if this vital sign is extended to include limber pine. In addition, this protocol will be implemented on six national forests (Bridger-Teton, Custer, Shoshone, Gallatin, Beaverhead-Deerlodge and Caribou-Targhee).

Justification/Issues being addressed: Whitebark pine occurs in the subalpine zone of the Pacific Northwest, where it is adapted to a harsh environment, often consisting of poor soils, steep slopes, high winds and extreme cold temperatures. This long-lived species is well known for its diverse growth forms ranging from straight and narrow to multi-stemmed, stunted and gnarled krummholz. Although its inaccessibility and often gnarled growth forms render whitebark pine of low commercial value, it is high in ecological value.

Whitebark pine is often considered a “keystone” species of the subalpine zone (Tomback et al. 2001). Because whitebark pine can become established under conditions tolerated by few other trees, its presence can alter the microclimate such that it enables other species, such as subalpine fir, to follow (Tomback et al 1993). Its occurrence on wind-swept ridges serves as a snow fence, thus playing an important role in snow accumulation. But, perhaps its best-known role in these ecosystems is as a food source for a variety of wildlife species. Whitebark pine seeds are large and high in fat content, making them a valuable food source for more than 17 wildlife species (Kendall and Arno 1990). Whitebark pine seeds are an especially important food source for grizzly bears, which can find them stockpiled in large quantities cached by red squirrels in middens (Mattson et al. 1992). In the Greater Yellowstone Ecosystem (GYE), this food source is so important that annual cone production in the GYE is one of the major predictors of annual survival and reproduction of the bears (Mattson et al. 1992).

Whitebark pine stands have been decimated in areas of the Cascades and northern Rocky Mountains due to the introduction of an exotic fungus—white pine blister rust—as well as mountain pine beetles (with a possible interaction effect between these sources of mortality). Our objectives are intended to estimate the current status of whitebark pine relative to infection with white pine blister rust as well as to assess the vital rates that would enable us to determine the probability of whitebark pines persisting in the Greater Yellowstone Ecosystem.

Monitoring Questions Addressed by the Protocol:

Some of the monitoring questions that will be addressed by this protocol include:

- What is the extent of white pine blister rust infection of whitebark pine throughout the Greater Yellowstone Ecosystem and is the rate of infection increasing?
- What is the severity of existing infections of white pine blister rust on whitebark pine and is the severity increasing?
- What is the survival of mature whitebark pine trees infected with white pine blister rust throughout the Greater Yellowstone Ecosystem and are mortality rates increasing?

Specific Monitoring Objectives:

Objective 1. To estimate the proportion of whitebark pine trees within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests) infected with white pine blister rust, and to determine whether that proportion is changing over time.

Justification/rationale for this objective.-- White pine blister rust has devastated whitebark pine in other parts of the Northwest (Kendall and Keane 2001, Koteen 2002), and anecdotal evidence suggests that it may be escalating in the GYE (Koteen 2002, D. Tomback pers. comm.).

Objective 2. To determine the relative severity of white pine blister rust infection in trees > 1.4 m in height within stands of infected whitebark pine within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests). Severity is indicated by the number and location (trunk or branch) of blister rust cankers.

Justification/rationale for this objective.-- Determining the proportion of trees infected with white pine blister rust can be misleading without a further understanding of the magnitude of the infection. Trees that are infected at low levels may persist for a considerable time in the absence of new infections and continue to produce seeds (Tomback et al. 2001). Trees that are infected on or near the trunk of the tree also have a greater risk of mortality and loss of reproduction (Zeglan 2002).

Objective 3. To estimate survival of individual whitebark pine trees > 1.4 m in height within the Greater Yellowstone Ecosystem (GRTE, YELL and six national forests), explicitly taking into account the severity of infection with white pine blister rust (from objective 2).

Justification/rationale for this objective.-- Trees that are infected at low levels may persist for considerable time (i.e., decades) in the absence of new infections, depending on where the tree is infected (Tomback et al. 2001, Koteen 2002). Estimating survival will enable us to distinguish the occurrence and severity of white pine blister rust from the ecological effect of infestation (i.e., loss of whitebark pine). Therefore, we will be better able to determine the vulnerability of whitebark pine in the Greater Yellowstone Ecosystem directly, rather than relying on potentially controversial extrapolation from other regions.

BASIC APPROACH:

An existing protocol has been developed by the Whitebark Pine Ecosystem Foundation (Tomback et al. 2004), although modification was needed to meet GRYN objectives and I&M standards, particularly related to site selection. In the existing protocol, the use of probability sampling is only suggested as one alternative, because of a perception that such an approach will be cost prohibitive. Judgment sampling (also known as the “relevé” method) is proposed as a viable alternative, which is unacceptable for I&M Standards, as it suffers from a high probability of selection bias that can greatly diminish the reliability of the sampling effort (Cochran 1977, Levy and Lemeshow 1999, Olsen et al. 1999). We have been working with partner organizations (USGS, U.S. Forest Service, the Greater Yellowstone Coordinating Committee, and the Statistics Department of Montana State University) to make revisions that will meet NPS standards but will make use of those parts of the existing protocol that are acceptable.

The basic approach will be a two-stage cluster design with stands (polygons) of whitebark pine being the primary units and 10x50 m plots being the secondary units. Plots are permanently monumented for repeated visits and individual trees > 1.4 m in height are marked for estimating survival. An ongoing pilot effort funded by USFS includes subsampling within stands in order for us to evaluate within- and between-stand variability. This effort will guide the final refinement of our sampling design.

The revisit design will be a rotating panel with approximately a five-year interval between surveys for a given panel (exact interval to be determined based on preliminary analysis of the pilot effort).

Principal Investigators and NPS Lead:

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Development Schedule, Budget, and Expected Interim Products:

The primary monitoring objectives have been developed and adopted by our partners, although two additional objectives are still being considered. An existing protocol had been developed for monitoring whitebark pine, although some modifications were necessary to meet the specific needs of the GRYN and to meet I&M program standards. Field testing of these revised methods was initiated during FY04 using USFS money. Some problems were encountered during this initial effort and solutions proposed. We are currently field testing these refinements during our 2005 effort, again using USFS money. We anticipate an advanced field tested protocol to be completed by late fall 2005 for peer review. We anticipate full implementation by summer of 2006. This will be a collaborative effort among several agencies. Further, the necessary sample size would be obtained over several years via the revisit design, thus should not entail an unreasonable cost to the NPS. The final budget will depend on final details of the objectives and sampling design. However, based on preliminary efforts, we anticipate an annual budget for NPS of approximately \$25,000, which will be matched by our partner organizations.

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